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Case Studies in Data Analysis

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Rainfall measurements were processed and evaluated, for future model development. Image and magnetic sensor data from polar orbiting satellites were processed, and data bases were updated.

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I. RAINFALL DATA PROCESSING AND ANALYSIS

I.1. INTRODUCTION

Data processing and analysis have been performed for forty-two individual rainfall measurement stations located throughout the United States. For most of these stations, the data were recorded for the entire ten-year period from January 1970 through December 1979, but data were recorded for a slightly different period for Urbana, and for shorter periods and selected months for San Sebastian (Puerto Rico), Kekaha (Hawaii), and Lalamilo (Hawaii) (see Table 1).

These data were initially recorded as weighing raingage measurements, and were converted to one-minute rainfall rates according to procedures described by Tattelman, Knight, and Scharr[1]. The data were then transferred by tape to the Geophysics Laboratory (GL) for further processing and analysis. The processing and display programs and procedures were initially developed by Bedford Research Associates for the GL CYBER system and peripherals, and were adapted and extended by RDP, Inc. for use on one of the GL VAX/VMS systems. Because the tapes were originally created on a VAX/VMS system, this system migration enabled the elimination of the data unpacking process on the CYBER in favor of a simple file copy process on the VAX. Furthermore, the VAX laser plotters could be used to generate the appropriate size and format plots more easily than the Calcomp drum plotter used by the CYBER.

Summary rainfall data were merged with climatological data for each station, to provide a basis for model development of rainfall patterns. Critical rainfall rates for the attenuation of radio wave transmissions were also obtained from the Environmental Technical Applications Center (ETAC) and were utilized in conjunction with the rainfall rate data to evaluate transmission outage occurrences for the individual station sites. These critical rates correspond to the climatological conditions appropriate to the individual sites for selected months, and are related to the transmission path lengths through the rainfall zone[2].

I.2. STANDARD PROCESSING

Each station is processed by first transferring the data from tape to a disk file on the VAX. The data are numeric ASCII values in 73-character records, with each record consisting of a

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[1] Tattelman, P., Knight, R.W., and Scharr, K.G. (5 March 1987) Estimates of Satellite EHF Communication Outages Due to Attenuation by Rain, AFGL-TR-87-0081, AD A183969

[2] Crane, R.K., Prediction of Attenuation by Rain, IEEE Transactions on Communications, Vol. 28, No. 9, Sep. 1980, pp 1717 - 1733

Rainfall Stations

Station site	Abbreviation	Data period
Aberdeen, SD	ABR	1-Jan-70:31-Dec-79
Albuquerque, NM	ALB	1-Jan-70:31-Dec-79
Allentown, PA	ALL	1-Jan-70:31-Dec-79
Asheville, NC	ASH	1-Jan-70:31-Dec-79
Bakersfield, CA	BAK	1-Jan-70:31-Dec-79
Billings, MT	BIL	1-Jan-70:31-Dec-79
Boise, ID	BOI	1-Jan-70:31-Dec-79
Boston, MA	BOS	1-Jan-70:31-Dec-79
Cape Hatteras, NC	CAP	1-Jan-70:31-Dec-79
Charleston, SC	CHA	1-Jan-70:31-Dec-79
Cheyenne, WY	CHE	1-Jan-70:31-Dec-79
Chicago, IL	CHI	1-Jan-70:31-Dec-79
Denver, CO	DEN	1-Jan-70:31-Dec-79
Ely, NV	ELY	1-Jan-70:31-Dec-79
Grand Junction, CO	GRA	1-Jan-70:31-Dec-79
Houston, TX	HOU	1-Jan-70:31-Dec-79
Huntsville, AL	HUN	1-Jan-70:31-Dec-79
Internat'l Falls, MN	INT	1-Jan-70:31-Dec-79
Kekaha, HI	KEK	1-Apr-77:30-Jun-78
Key West, FL	KEY	1-Jan-70:31-Dec-79
Lalamilo, HI	LAL	1-Mar-77:31-Dec-77
Lexington, KY	LEX	1-Jan-70:31-Dec-79
Miami, FL	MIA	1-Jan-70:31-Dec-79
Newark, NJ	NEW	1-Jan-70:31-Dec-79
NYC (Kennedy), NY	NYK	1-Jan-70:31-Dec-79
Oklahoma City, OK	OKL	1-Jan-70:31-Dec-79
Omaha, NE	OMA	1-Jan-70:31-Dec-79
New Orleans, LA	ORL	1-Jan-70:31-Dec-79
Philadelphia, PA	PHI	1-Jan-70:31-Dec-79
Phoenix, AZ	PHO	1-Jan-70:31-Dec-79
Pittsburgh, PA	PIT	1-Jan-70:31-Dec-79
Raleigh, NC	RAL	1-Jan-70:31-Dec-79
Rapid City, SD	RAP	1-Jan-70:31-Dec-79
San Angelo, TX	SAA	1-Jan-70:31-Dec-79
San Sebastian, PR	SAB	1-Feb-73:30-Sep-73; 1-Feb-74:30-Nov-79
Santa Maria, CA	SAM	1-Jan-70:31-Dec-79
Seattle, WA	SEA	1-Jan-70:31-Dec-79
Shreveport, LA	SHR	1-Jan-70:31-Dec-79
Spokane, WA	SPO	1-Jan-70:31-Dec-79
St. Louis, MO	STL	1-Jan-70:31-Dec-79
Tallahassee, FL	TAL	1-Jan-70:31-Dec-79
Topeka, KS	TOP	1-Jan-70:31-Dec-79
Urbana, IL	URB	1-Jun-69:31-Aug-79
Yuma, AZ	YUM	1-Jan-70:31-Dec-79

Table 1

3-character code, followed by a 10-character date and time identifier, followed by 15 4-digit values representing the rainfall rates in hundredths of a millimeter per minute for each of the 15 minutes beginning at the time label for the record. The initial code consists of a 1-character status code followed by a 2-character station identifier. Extended periods with no rainfall are designated by an absence of records, while periods of rainfall for which the data are missing are designated by a status code 2, with the estimated rainfall rate being the average rainfall computed from the total rainfall for that one-hour period.

The time sequence of the data was checked for all data files, insuring proper date and time ordering, and valid dates and times, for all data records.

The individual data files for each site are named according to the station identifier, derived from the city and airport location of each station. These identifiers are listed in Table 1. The suffix "_RAWDATA" is appended to each of these station identifiers for the data file name, and "DAT" is used as the file extension.

A set of data bases associated with each site is derived, based on the tabulations of the total number of rainfall minutes above selected rainfall rate thresholds and on the number of continuous rainfall minutes above selected rainfall rate thresholds. These tabulations are performed on an annual, monthly, and diurnal basis, using the rainfall rate thresholds in Table 2. For these data bases, the filename prefixes are given by the station identifier abbreviations, and the filename suffixes are assigned according to Table 3, based on the period for the tabulation and the rainfall durations included in the file. The file extensions are all "DAT".

Additional data bases are constructed for Poisson probability parameters, which are utilized for the evaluation of rainfall duration probabilities, as described in Reference 1. The suffix used to identify these files is "_PROB", and the "DAT" extension is also used.

For each station, sets of evaluation plots for rainfall conditions are generated. Primary among these are plots for the average number of rainfall occurrences at or above a specified threshold rainfall rate, for selected durations of continuous rainfall, for the entire year, for each season, and for the individual months. A sample plot for Boston is shown in Figure 1.

A secondary set of plots displayed the probability for the number of occurrences of rainfall events above selected rainfall rate thresholds. These plots are based on the derived Poisson probability parameters. A sample plot for Boston is displayed in Figure 2.

A further set of plots which was developed for application to the rainfall data was a pointwise plot of the relationship between rainfall duration and the number of occurrences of such durations, for a selected set of rainfall rate thresholds. These plots display the number of occurrences as a logarithmic abscissa and the duration, in minutes, as a logarithmic ordinate, but it is the number of occurrences which is considered to be a

Rainfall Rate Threshold Values
(in millimeters per minute)

Annual/ Monthly Tabulations		Diurnal Tabulations
0.001	1.00	0.001
0.05	1.10	0.05
0.10	1.20	0.10
0.15	1.30	0.15
0.20	1.40	0.25
0.25	1.50	0.375
0.30	1.60	0.50
0.35	1.70	0.625
0.40	1.80	0.75
0.45	1.90	0.875
0.50	2.00	1.00
0.55	2.10	1.125
0.60	2.20	1.50
0.65	2.30	1.75
0.70	2.40	2.00
0.75	2.50	
0.80		

Table 2

function of the duration, for each threshold rainfall rate. A sample plot for Boston is displayed in Figure 3.

I.3. SYSTEM OUTAGE EVALUATIONS

A significant application for the rainfall rate data is with respect to EHF (above 10 GHz) communications, which can be seriously affected by heavy rainfall. The influence of rainfall on communications is not based strictly on the intensity of the rainfall, but rather on the transmission path length through the rainfall region, as discussed in Reference 2. Thus, the elevation angle for the transmission path, as well as the altitude for the freezing level, are contributing factors to the signal attenuation. Furthermore, the rainfall rate attenuation effect is dependent on the transmission frequency.

A fundamental assessment of the effects of rainfall for a particular site is presented in the tables for rainfall event occurrences. These tables display the threshold rainfall rates for specified probabilities of occurrence of rainfall events defined by a minimal number of occurrences of rainfall above the specified threshold rate for specified threshold durations. More severe cases for EHF transmissions are characterized by low rainfall rates associated with high probabilities, while less severe cases are characterized by high rainfall rates

Suffixes for Rainfall Duration Data Bases

Annual Tabulations

Suffix	Threshold Durations (minutes)
_A123	1, 5, 10
_A456	15, 20, 25
_A78	30, 35

Monthly Tabulations

Suffix	Threshold Durations (minutes)
_M12	1, 5
_M34	10, 15
_M56	20, 25
_M78	30, 35
_M910	40, 45
_M1112	50, 55
_M1314	60, 65

Diurnal Tabulations

Suffix	Threshold Durations (minutes)
_TS18	1, 5, 10, 15, 20, 25, 30, 35

Table 3

associated with high probabilities. A sample table is given as Table 4.

A more refined evaluation can be performed if the critical rainfall rate corresponding to a designated degree of attenuation for a specified transmission path is already known. This critical rate will be influenced by the local climatological and geographical conditions, particularly the altitude of the freezing level and the height above sea level of the transmitting station. These critical rates were calculated by ETAC for GL for the conditions specified in Table 5. These critical rates were then incorporated with the tabulated rainfall statistics to generate direct tables for occurrence probabilities of transmission outages. The outage probabilities are also computed for multiple numbers of critical rainfall occurrences.

Two alternative sets of tables are also generated for the evaluation of system outages at individual sites. One set presents the estimated number of outages for a calendar month, for specified outage durations, while the other presents the percentage of time lost to

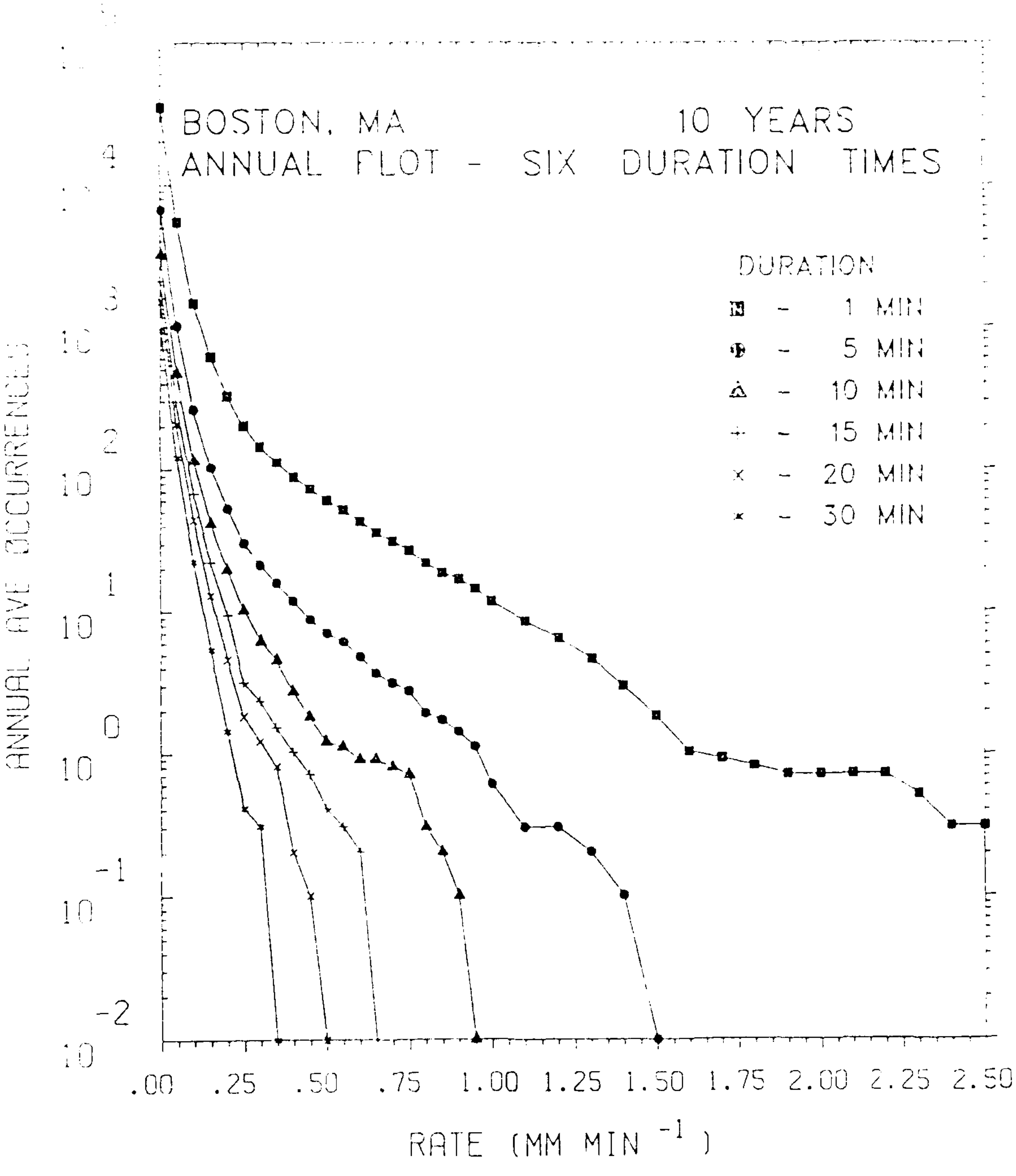
BOSTON, MA
10 YEARS
ANNUAL PLOT - SIX DURATION TIMES
DURATION
▣ - 1 MIN
● - 5 MIN
▲ - 10 MIN
+ - 15 MIN
× - 20 MIN
* - 30 MIN
ANNUAL AVE OCCURRENCES
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
.00
.25
.50
.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
RATE (MM MIN^-1)

Figure 1

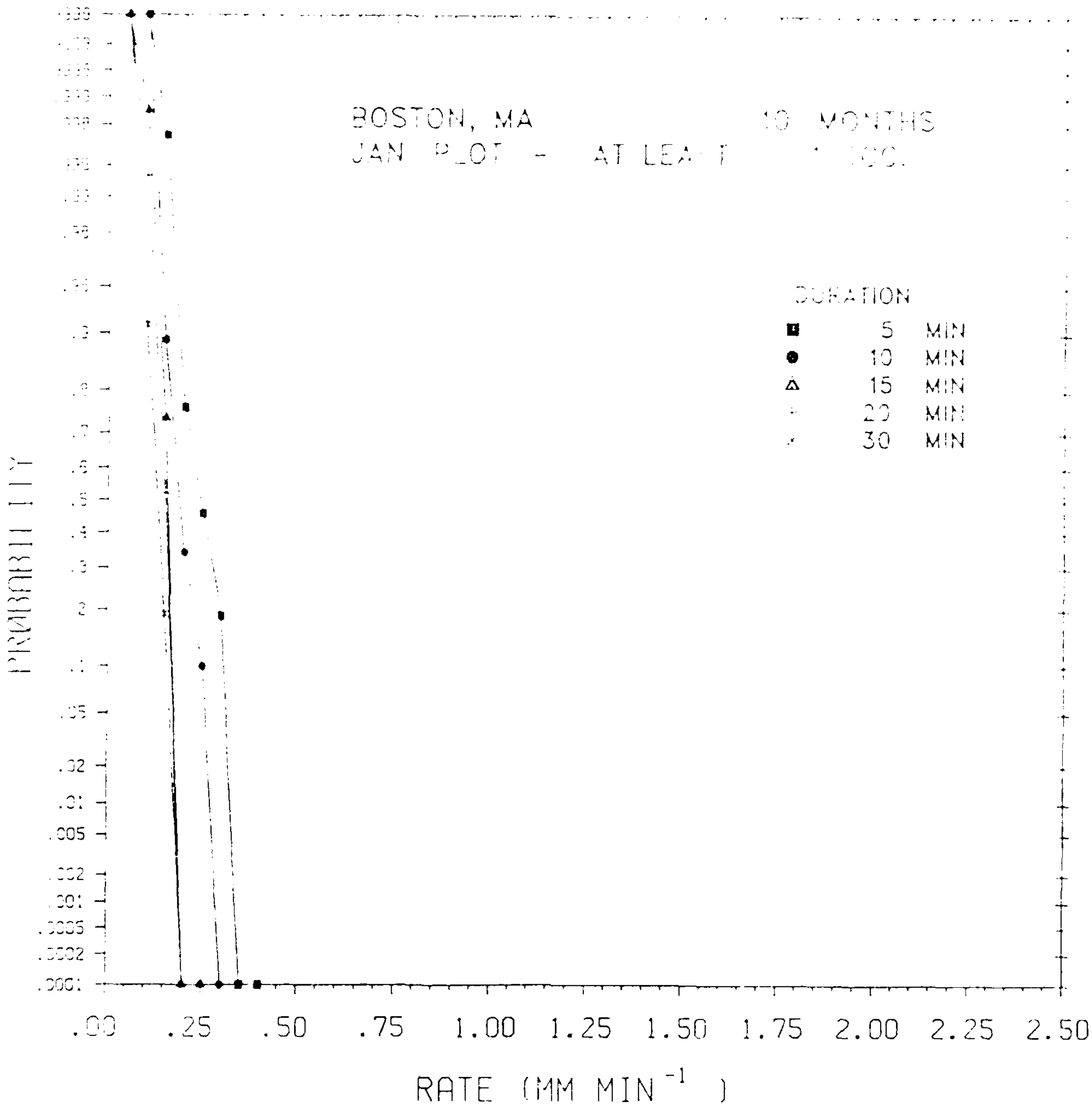
BOSTON, MA
10 MONTHS
JAN PLOT - AT LEAST
DURATION
5 MIN
10 MIN
15 MIN
20 MIN
30 MIN
PROBABILITY
.9
.8
.7
.6
.5
.4
.3
.2
.1
.05
.02
.01
.005
.002
.001
.0005
.0002
.0001
.00
.25
.50
.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
RATE (MM MIN^{-1})

Figure 2

Threshold Rainfall Rates for Specified Probabilities

One-min Rainfall Rate Versus Duration and Probability of at Least 1 Occurrence for All Months at Boston, MA and New Orleans, LA

Location	Month	Rainfall Rate (mm/min)														
		Duration (min)														
		5			10			15			[illegible]			[illegible]		
		Probability			Probability			Probability			Probability			Probability		
		0.1	0.5	0.9	0.1	0.5	0.9	0.1	0.5	0.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Boston, MA	JAN	0.31	0.24	0.13	0.25	0.19	0.15	0.17	0.16	0.14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Boston, MA	FEB	0.35	0.26	0.20	0.30	0.22	0.16	0.25	0.18	0.13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Boston, MA	MAR	0.40	0.26	0.18	0.26	0.19	0.14	0.25	0.16	0.11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Boston, MA	APR	0.58	0.22	0.16	0.25	0.16	0.13	0.20	0.14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Boston, MA	MAY	0.35	0.27	0.23	0.30	0.23	0.18	0.22	0.20	0.14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bosto., MA	JUN	0.94	0.60	0.37	0.45	0.36	0.27	0.35	0.23	0.14	[illegible]	0.19	[illegible]	[illegible]	[illegible]	[illegible]
Boston, MA	JUL	1.28	0.75	0.45	0.75	0.42	0.24	0.45	0.27	0.16	0.31	0.20	0.12	0.21	0.13	[illegible]
Boston, MA	AUG	1.19	0.86	0.48	0.90	0.47	0.26	0.60	0.33	0.16	0.36	0.22	0.13	0.30	0.11	[illegible]
Boston, MA	SEP	0.99	0.60	0.42	0.79	0.40	0.23	0.59	0.24	0.18	0.45	0.25	[illegible]	[illegible]	0.17	[illegible]
Boston, MA	OCT	1.37	[illegible]	0.25	0.73	0.28	0.19	0.49	0.22	0.15	0.34	0.19	0.13	0.20	0.15	[illegible]
Boston, MA	NOV	0.35	0.24	0.19	0.26	0.20	0.16	0.21	0.18	0.14	0.20	0.16	0.13	0.20	0.14	[illegible]
Boston, MA	DEC	0.82	0.22	0.18	0.40	0.19	0.15	0.21	0.17	0.13	0.21	0.15	0.11	0.16	0.13	[illegible]
New Orleans, LA	JAN	1.30	0.91	0.60	1.10	0.57	0.34	0.80	0.41	0.24	0.50	0.29	0.20	0.45	0.22	[illegible]
New Orleans, LA	FEB	1.77	0.94	0.72	0.90	0.60	0.38	0.72	0.43	0.25	0.64	0.30	[illegible]	0.49	0.24	[illegible]
New Orleans, LA	MAR	1.04	0.88	0.65	0.85	0.62	0.43	0.74	0.39	0.30	0.65	0.33	0.22	0.35	0.21	[illegible]
New Orleans, LA	APR	2.47	1.14	[illegible]	1.04	0.68	0.41	0.95	0.48	0.27	0.75	[illegible]	[illegible]	0.44	0.23	[illegible]
New Orleans, LA	MAY	1.50	1.20	0.87	1.04	0.76	0.54	0.80	0.58	0.38	0.80	0.45	0.25	0.69	0.32	[illegible]
New Orleans, LA	JUN	1.60	1.28	0.99	1.20	0.99	0.64	1.10	0.79	0.47	1.10	0.65	0.34	0.70	0.36	[illegible]
New Orleans, LA	JUL	2.49	1.71	0.96	1.99	1.13	0.63	1.49	0.68	0.43	1.47	0.46	0.30	1.26	0.28	[illegible]
New Orleans, LA	AUG	2.38	1.78	1.23	1.76	1.32	0.73	1.64	0.87	0.50	1.54	0.71	0.37	1.45	0.36	[illegible]
New Orleans, LA	SEP	1.74	1.31	1.03	1.30	0.89	0.62	1.14	0.75	0.41	0.84	0.51	0.34	0.59	0.20	[illegible]
New Orleans, LA	OCT	2.03	0.98	0.64	1.29	0.71	0.34	0.80	[illegible]	0.21	[illegible]	0.36	0.15	0.33	[illegible]	[illegible]
New Orleans, LA	NOV	2.39	1.22	0.54	1.89	0.48	0.33	1.86	0.44	0.26	1.56	[illegible]	[illegible]	0.97	[illegible]	[illegible]
New Orleans, LA	DEC	1.34	1.05	0.49	1.00	0.75	0.39	0.65	0.46	[illegible]	[illegible]	0.33	0.22	0.44	[illegible]	[illegible]

Table 4

Conditions for Critical Rainfall Rates

Fade Margins:	15 dB, 20 dB, 25 dB
Transmission Frequencies:	15 GHz, 30 GHz, 45 GHz
Transmission Elevation Angles:	10°, 30°, 50°, 70°
Months:	January, April, June, July, August, October

Table 5

outages, relative to the total operating time for a calendar month.

I.4. RAINFALL DURATION ANALYSIS

As a preliminary stage to the development of a more extensive climatological model for rainfall patterns, an analysis was performed to determine a functional relationship for the number of occurrences of rainfall durations above threshold rainfall rates, as a function of the rainfall duration and parametrized by the rainfall rate. In subsequent analyses, the parameters incorporated into the functional form will be related to climatological parameters.

A sample set of rainfall duration data is displayed in Figure 3 for Boston for the month of August. The tabulation for number of occurrences is performed such that an extended rainfall duration, greater than the specified duration period, is counted as the maximal number of disjoint intervals of the specified duration period. Thus, for each rainfall rate threshold, there is an upper envelope for the number of occurrences (N) versus duration in minutes (D), defined by N x D = constant, with the constant being the total number of rainfall minutes at or above that rainfall rate threshold.

A further attribute of the data is that, for any duration period, there can be no fewer occurrences for a given rainfall threshold rate than at the next higher threshold rate. This is a direct consequence of the thresholding process. To preserve this attribute in the functional forms, it is necessary that the functions between occurrences and durations not intersect for different rainfall threshold parameters, although the functions could meet tangentially.

The first analysis into these relationships was based on the earlier work of Ajayi and

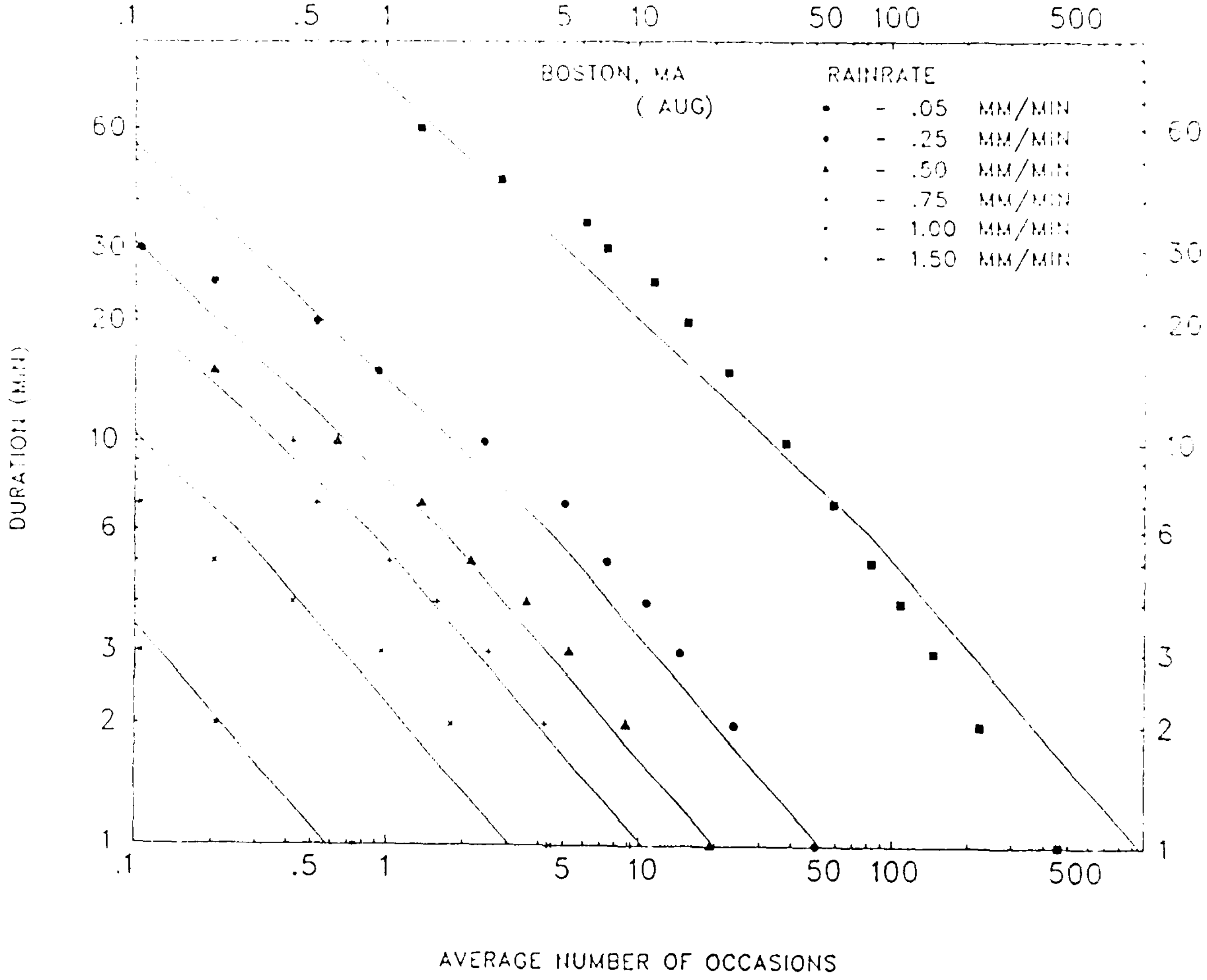
BOSTON, MA
(AUG)
RAINRATE
● - .05 MM/MIN
● - .25 MM/MIN
▲ - .50 MM/MIN
+ - .75 MM/MIN
× - 1.00 MM/MIN
· - 1.50 MM/MIN
DURATION (MIN)
AVERAGE NUMBER OF OCCASIONS
.1
.5
1
5
10
50
100
500
1
2
3
6
10
20
30
60

Figure 3

Ofoche[3], which used individual linear fits in the logarithm of the number of occurrences versus the logarithm of the duration, for each threshold rain rate. For their data set, and for many of the early data sets used in this study, the individual linear fits for the different threshold rainfall rates are non-intersecting within the domain of the graph, but the linear fits were not parallel, and thus would intersect for some value of the rainfall duration. For later data sets used in this study, the intersection of the linear fits is quite apparent, and invalidates the predictions of the model.

A formulation which avoids this situation was developed, in which a common log-log slope is derived for all of the rainfall threshold sets, and the N versus D relationship is characterized by different intercepts on the log-log plot for the different rainfall thresholds. An efficient mathematical algorithm was devised to perform these correlated linear fits, and data from a number of sites were evaluated according to this model. The overall fit for the data sets at each site was reasonable, but the curvature of the data on the log-log plot was not adequately portrayed by the linear fits.

To further elaborate on this model formulation, an algorithm for performing correlated "hinged" fits was devised, in which two distinct slopes are invoked for each rainfall rate threshold, and the junction between the two slopes occurs at a pre-determined rainfall duration. As with the correlated linear fits, the different rainfall thresholds share a common pair of slopes, and each rainfall rate threshold is associated with a unique intercept, but the position of the "hinge" is not necessarily at the same duration for all rainfall rate threshold values.

The correlated "hinge" fits gave results which better represented the data values than did the linear fits, but the degree of improvement was conditional on the proper choice of the "hinge" position. The formulation of the "hinge" fits becomes highly non-linear if the "hinge" positions are considered variable, rather than fixed, and an iterative solution scheme would probably be the best approach for future implementation. However, an independent development of correlated quadratic fits has been applied to these data sets, and satisfactory results have been obtained by that formulation, so the "hinge" fit developments have been discontinued.

---

[3] Ajayi, G.O., and Ofoche, E.B.C., Some Tropical Rainfall Rate Characteristics at Ile-Ife for Microwave and Millimeter Wave Applications, Journal of Climate and Applied Meteorology, Vol. 23, No. 4, pp. 562-567

II. HILAT/POLAR BEAR ANALYSES

II.1. HILAT/POLAR BEAR SPACECRAFTS

The HILAT spacecraft, designated P83-1, was launched into polar orbit on a Scout rocket on 27 June 1983 from Vandenburg AFB. The HILAT payload was designed to provide data for the study of plasma density irregularity dynamics in the high latitude ionosphere. The spacecraft orbit is nearly circular at 800 km with an orbital period of approximately 101 minutes. In addition, the vehicle is nearly three-axis stabilized (drifts in pitch, yaw, and roll can be seen on each acquisition).

The Polar BEAR satellite was launched in 1986 from Vandenburg AFB. This polar orbiting vehicle, similar in design to HILAT, has an inclination of 82 degrees. The orbit is approximately 930 km by 1070 km, which results in an orbital period of approximately 105 minutes.

HILAT and Polar BEAR operate in real time mode only. Data is downlinked to any of four ground stations. Three of these stations are at fixed high latitude sites (Tromso, Norway; Sondrestrom, Sweden; and Fort Churchill, Canada). The remaining station, referred to as the Rover, is moveable. The Rover is most frequently located in Seattle, Washington.

II.2. HILAT/POLAR BEAR PAYLOAD SUMMARY

The HILAT payload consists of a coherent beacon which provides scintillation and total electron content data; a Thermal Plasma Monitor which consists of an Electron Sensor, Retarding Potential Analyzer (RPA), and Ion Driftmeter (IDM); an Electron Spectrometer for the measurement of electron flux in the energy range between 20 eV and 20 keV; the Auroral Ionospheric Mapper (AIM) which consists of a scanning imager (which failed on 23 July 1983) and two photometers; and a triaxial fluxgate magnetometer. Attitude data is computed using the triaxial magnetometer along with a sun sensor.

The payload for Polar BEAR includes the Auroral Ionospheric Remote Sensor (AIRS), the beacon, and the triaxial fluxgate magnetometer. The AIRS is a more sophisticated version of the AIM detector which was flown on HILAT. It obtains simultaneous multispectral UV and visual images during both daylight and night operations. The beacon, similar in design to the one flown on HILAT, is used to measure scintillation effects at radio frequencies used for radar and communications. The magnetometer is also similar in design to the system used on HILAT. It is used to measure field-aligned currents as well as provide input for attitude determination along with the digital sun sensor. These three instruments are operated concurrently in real time mode over the remote stations.

II.3. DATA FLOW

The functional data flow for both vehicles is the same. For each station pass, the downlinked data is digitized by the station computer onto a disk file of the raw telemetry data. Between station passes, the raw data is semi-processed and put onto a disk file in "Summary Tape" form. The raw data files are off-loaded onto "Raw Tapes" and the "Summary files" off-loaded onto tapes referred to as Summary Tapes.

Upon receipt of a shipment of Summary Tapes at the Geophysics Laboratory (GL), the tapes are quality checked, copied and shipped to outside agencies, and reformatted for use in analysis routines.

Data on the raw tapes consists of station coordinates, Keplerian elements, spacecraft position, time tagged raw telemetry data in packed form, and raw scintillation data. Raw tapes from Tromso are received at GL where they are logged and archived.

The Summary Tape structure consists of interlaced records which contain time, geometry and model magnetic field data; raw telemetry data; scintillation summary data; and science summary data. Each file contains data from one station pass.

Due to the great similarities between the two spacecraft, a commonality of requirements frequently existed in the data base development procedures for the vehicles. Thus, common formats were defined for data from *similar sensors.* In addition, the Scientific Satellite Data Analysis System (SSDAS) included a library of software tools designed to have application for both spacecraft.

II.4. ANALYSES

II.4.1. QUALITY CHECK/DATA DISSEMINATION

Upon receipt of a shipment of HILAT or Polar BEAR Summary Tapes, the quality check (Q/C) effort was immediately initiated in order to keep up with the volume of data from these vehicles. Problems which were detected through the Q/C procedure included missing passes, improper interlacing of the data record types, improper time spacing between records, improper time tagging, and buffer overflow data which results in incorrect data values. Handwritten logs of station pass information are maintained at each of the stations and copies of these logs are received at GL. These logs were useful in determining possible problem passes.

II.4.2. HILAT ANALYSES

The scintillation data base was routinely created for HILAT and Polar BEAR during the period of this contract. This data base consisted of parameters contained on the Time/Geometry/Magnetic Field records along with the scintillation records from the Summary Tape. An analysis for the determination of scintillation statistics analysis was designed which used the scintillation data base as input; extracted data segments based on quantized time periods; averaged parameters based on ephemeris constraints; and created the scintillation statistics data base. Analysis techniques and computer routines were developed to input the statistics data base and perform further statistical analyses.

During the contractual period, the processing of sensor data for HILAT was done on a selective basis (usually in support of scintillation studies). Succeeding paragraphs in this section will briefly describe the analyses performed for these sensors.

The GL payloads on HILAT consist of the AIM, Electron Spectrometer, and Thermal Plasma Monitor. The data bases for these instruments, as well as the magnetometer, were created in time history form. These data bases were then used as input to modular routines which produce displays of the computed parameters. For the Electron Spectrometer, Thermal Plasma Experiment, and Magnetometer, two types of displays were produced: summary and detailed.

Each summary display covers data for an entire pass and consists of averaged data. These displays provide a survey of the instrument data on a pass by pass basis.

The detailed displays contain high sample rate data displayed on a sequence of time overlapped frames. These displays are useful for event studies. The displays for each of the instruments are on common time scales to allow for correlation.

For the Thermal Plasma Experiment, the analysis package consists of modules for each of the three independent experiments. For these experiments, data is read out of telemetry in 64-second blocks which can be further subdivided into 8-second segments. The initial effort consists of identifying the beginning of an 8-second block and determining the subsection number within the 64-second cycle. Once found, the data is accumulated in 64-second groups. These 64-second sections contain all readouts for the Electron Sensor, RPA, and IDM.

The Electron Sensor is used to obtain electron density and frequency data. During the swept portion of the instrument cycle, the beginning of each sweep must be determined and the telemetry values converted to sweep voltage. The sensor output is converted to telemetry voltage and then to current. The sensor potential is then calculated from the subcommutated data. A modular routine developed for electron density determination then receives an array of ordered pairs of sweep voltage and current along with sensor potential. The routine returns electron density, electron temperature, and vehicle potential with respect to the plasma. Electron frequency data is also obtained at 4 fixed frequency values. The root-mean-square (RMS) values for each of the frequencies are then computed.

The RPA data consists of 2- and 4-second sweeps. Modules were developed to determine the beginning of each 2- and 4-second sweep and convert the telemetry values to sweep voltage and measured current. A modular routine then receives as input the ordered pairs of voltage and current along with total spacecraft velocity and sensor potential and computes the ion temperature and drift velocity of ions normal to the RPA aperture.

The IDM cycle is 8 seconds. The horizontal and vertical velocity telemetry values are converted to horizontal and vertical drift tangents. From the tangent data, another modular routine is used to compute ion density and the drift velocities.

The Electron Spectrometer, referred to as the J-Sensor, has three modes of operation. Three sensors are mounted at zenith, 40 degrees from zenith, and nadir. Mode 1 consists of zenith data with 8 points per spectra; mode 2 consists of zenith data with 16 points per spectra; and mode 3 results in data acquisition from all three detectors. Once the instrument mode is identified, data is accumulated into 1-second blocks. The J-Sensor data base consists of structured records which identify instrument mode, the deconvolved instrument counts arranged from lowest to highest energy, decompressed magnetometer counts, and selected ephemeris parameters. A modular routine which has the calibration parameters stored as a function of time from launch is used whenever differential flux or distribution function computations are required. The deconvolved magnetometer counts were included in the J-Sensor data base because magnetic pitch angle is often required in the interpretation of differential flux data.

II.4.3. POLAR BEAR ANALYSES

The prime data involved in Polar BEAR analyses during the contractual period consisted of the AIRS data and the scintillation data. Scintillation analysis efforts were identical to those performed for HILAT.

The initial input data for Polar BEAR SSDAS applications consists of the reformatted Summary Tape (which is in a similar format to that received for HILAT).

The AIRS sensor consists of four integrated detectors each of which obtains 326 pixel values per line scan. The time duration of a line scan is 2.9987 seconds. The data for each line scan is read out over 6 SDF telemetry frames. Also contained in these 6 frames is the AIRS housekeeping data along with sequencer and status words.

The instrument can be operated in any of three modes: imaging, spectrometer and photometer.

In imaging mode, a mirror line scan of 326 pixels for each of the four detectors takes place.

Each step corresponds to approximately .4 degrees. Although the instrument actually moves through 336 steps, no data is taken in the first and last 5 steps. Only the data from the 326 good pixels is read out to telemetry. The full mirror scan corresponds to plus and minus 67.2 degrees from nadir. At the end of each forward scan, the mirror direction is reversed by stepping the motor at 4 times the forward scan rate. The wavelengths chosen for detectors 1 and 2 are commandable. For detectors 3 and 4, the wavelengths are restricted to a choice of 2 values for each sensor.

In photometer mode, the mirror is fixed at nadir. As in imaging mode 336 pixels are read out over 6 SDF telemetry frames but valid photometer data is obtained for all pixels except the first and last 5. In this mode, detectors 1 and 2 are used for VUV measurements while detectors 3 and 4 are for UV measurements.

Spectrometer mode has the mirror fixed at nadir while the wavelength range is swept. Detector 1 covers the wavelength range from 1189 to 2164 Angstroms while detector 2 scans the range from 924 to 1924 Angstroms. Of the 336 pixel values read out over the 6 SDF telemetry frames, valid spectrometer data is obtained from pixels 6 through 331. In this mode, detectors 3 and 4 operate as photometers.

The AIRS data base was designed to allow for ready input into follow-on analysis and display routines. The data base consists of structured records which correspond to a full set of pixel readouts (starting at pixel 1 and ending at the last pixel).

Decompressed counts are stored in packed form to minimize storage requirements. The frames are time tagged to the beginning of the scan. Selected ephemeris and magnetic parameters as well as vehicle pitch, yaw and roll are extracted from the Time/Geometry/Magnetic Field records on the summary tape and stored in each data base record. In addition, the magnetometer data is stored in compressed and packed form. By storing the magnetometer data in compressed counts, data base compaction is further enhanced.

All instrument housekeeping data are included in the data base. Each data base file represents data from one pass.

Since there is a great similarity between the AIRS sensor and the AIM instrument which was flown on HILAT, many techniques developed to handle the AIM data had direct application for AIRS. Moreover, many of the computer modules in the HILAT subroutine library had direct application, while others required only minor modification.

The AIRS telemetry consists of 221 8-bit words per SDF frame. A full set of AIRS readouts is acquired over 6 telemetry frames. The first of the 221 words in each frame contains the AIRS line counter which cycles from 1 to 6 along with one sequencer A value. There are five A sequencers and one B sequencer which are used to control the instrument.

In each of the instrument modes, lines 1 through 5 in the telemetry are of the same form: the identifier word followed by 220 pixel readouts. There are 55 readouts for each of the four detectors on each of the first 5 lines of telemetry. For the sixth line, the first word is the identifier word; the next 204 words contain pixel data (structured as in the previous 5 frames); and words 206-221 contain instrument housekeeping and status information. There are 16 AIRS housekeeping words which are read out in 4 groups of 4 words.

The prime functions of the A sequencers are reflected in the table below:

SEQ NO.	FUNCTION
A0	Selects one of 16 wavelength positions for imaging or photometer mode.
A1	Selects imaging, photometer or spectrometer mode.
A2	Controls backup functions, such as increasing power for the spectrometer grating motor.
A3	Selects test modes.
A4	Switches power off to any of the 4 detectors.
A5	Controls spectrometer grating mode selection and other housekeeping functions.

The B sequencer is used to select the A sequencer which is to be commanded.

The AIRS data base routine:

- Determines the first occurrence of a line counter value of 1. This initiates the processing for the pass.
- Tests for telemetry dropout and 1's fill within scans as necessary.
- Interpolates ephemeris/magnetic/attitude data to the time at the beginning of the line scan.
- Extracts and decompresses pixel counts for each detector.
- Structures data by detector in packed word form.
- Extracts and retains AIRS status and housekeeping data.
- Extracts and retains data from the science magnetometer.
- Generates 2 data base header records followed by structured AIRS data base records.

II.4.4. AIRS DATA BASE FORMAT

The AIRS data base is generated on a satellite pass per file basis. The data base is archived on 9-track digital tape at a density of 6250 bpi. Each tape contains the data from at least one Summary Tape.

Each data base file consists of 2 preface (or header) records followed by a series of AIRS data base records.

PREFACE RECORD 1

This record consists of 15 words.

Word No.	Description
1	Year (F)
2	Day of year (F)
3	Latitude of station (F)
4	Longitude of station (F)
5	AIRS operating mode at beginning of the pass (F) 1.=Imaging, 2.=Spectrometer, 3.=Photometer
6	Start time of pass - UT seconds (F)
7	Run date of file creation (A)
8	Run time of file creation (A)
9	Wavelength of Detector 1 (-1. if in spectrometer mode)
10	Wavelength of Detector 2 (-1. if in spectrometer mode)
11	Wavelength of Detector 3 (-1. if in spectrometer mode)
12	Wavelength of Detector 4 (-1. if in spectrometer mode)
13-15	Vacant

PREFACE RECORD 2

This record contains satellite ephemeris, magnetic, and attitude data extracted from the Summary Tape. Data stored in this record are written in block form to allow for interpolation of parameters not stored on data base records. The time spacing between blocks is 15 seconds (as on the Summary Tape). There are 45 parameters contained in each block. A leading integer word is provided to indicate the number of blocks in the record (since record size will vary depending on the time duration of the pass). No pass should exceed 30 minutes and thus the record will not be larger than 5401 words. All words are in Control Data 60-bit floating point form.

The order of the 45 words in each block is as follows:

Word No.	Description
1	UT - seconds
2	Geodetic latitude - deg
3	Longitude (+E) - deg
4	Geodetic altitude - km
5	Geocentric position X - km

6 " " Y - km
7 " " Z - km
8 Geocentric velocity X - km/sec
9 " " Y - km/sec
10 " " Z - km/sec
11 Pitch - deg
12 Yaw - deg
13 Roll - deg
14 Invariant mag. latitude (APL eccentric dipole) - deg
15 Magnetic local time (APL eccentric dipole) - sec
16 Magnetic dip - deg (IGRF 85)
17 Magnetic declination - deg (IGRF 85)
18 Magnetic strength North - mG (IGRF 85)
19 " " East - mG (IGRF 85)
20 " " Vertical - mG (IGRF 85)
21 Solar right ascension - deg
22 Solar declination - deg
23 Solar zenith angle - deg
24 Sun/shade angle - deg
25 Invariant mag. lat. (Gustafsson model) - deg
26 Magnetic longitude (Gustafsson model) - deg
27 Magnetic local time (Gustafsson model) - hrs
28 350 km geodetic latitude - deg
29 " longitude - deg
30 " altitude - km
31 " solar zenith angle
32 " Sun/shade angle - deg
33 100 km geodetic latitude - deg
34 " longitude - deg
35 " altitude - km
36 " solar zenith angle - deg
37 " Sun/shade angle - deg
38 Surface geodetic latitude - deg
39 " longitude - deg
40 " altitude - km
41 Inv. Mag. Lat. of F-region penetration - deg
42 Magnetic local time of F-region penetration - hrs
43 Code word (0. = no science summary record on Summary Tape; 1. = science summary record on tape)
44 Vacant
45 Vacant

AIRS DATA BASE RECORDS

There are 419 60-bit words per record.

Word No.	Description
1	Mode indicator (1.=Imaging; 2.=Spectrometer; 3.=Photometer)
2	Test status (1.=Normal; 2.=Dark shutter; 3.=Optical test; 4.=Extended dark shutter)
3	TLM status (0.=normal; 1.=some words 1's filled)
4	Detector 1 wavelength (-1. if spectrometer mode)
5	Detector 2 wavelength (-1. if spectrometer mode)
6	Detector 3 wavelength (-1. if spectrometer mode)
7	Detector 4 wavelength (-1. if spectrometer mode)
8	UT - sec
9	Altitude - km
10	Longitude - deg
11	Vacant
12	Geodetic latitude - deg
13	Vacant
14	Invariant mag. lat. (Gustafsson model) - deg
15	Magnetic longitude (Gustafsson model) - deg
16	Magnetic local time (Gustafsson model) - hrs
17	Solar zenith angle
18	Sun/shade angle - deg
19	X position - km
20	Y position - km
21	Z position - km
22	X velocity - km/sec
23	Y velocity - km/sec
24	Z velocity - km/sec
25	Pitch - deg
26	Yaw - deg
27	Roll - deg
28	Invariant mag. latitude (APL eccentric dipole) - deg
29	Magnetic local time (APL eccentric dipole) - sec
30	B-North - mG
31	B-East - mG
32	B-Vertical - mG
33	SDF frame count
34	AIRS line counter
35-40	Vacant
41-87	Magnetometer data stored in 15-bit words. (There are 31 15-bit magnetometer words for each SDF frame. There are 10 words for the X, Y,

	and Z magnetometers and one flag word. The groups of 10 words represent one B-field measurement and 9 delta-B values. Six such frames (accumulated over the AIRS scan) are stored. The 30 LSB's of word 87 are vacant.)
88-169	Detector 1 pixel data
170-251	Detector 2 pixel data
252-333	Detector 3 pixel data
334-415	Detector 4 pixel data
	(The telemetry counts for the 326 pixel words from each detector are decompressed and stored in 15-bit words. This results in 82 CDC words per detector. The 30 LSB's of the 82nd word for each detector are vacant.)
416-419	AIRS status and housekeeping words. (The 16 telemetry words (206-221) from line count 6 are retained in counts and stored into 15-bit words.)

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